Brief History of NWSRFS

by Eric Anderson

Back in the 1960's each RFC had a unique system for generating operational forecasts. As computers became available most RFCs programmed their existing techniques in-house. In a few cases some outside assistance was solicited and in other cases programs were obtained from another RFC and then modified in-house to accommodate the way the RFC was doing business. The majority of the RFCs used API based techniques for rainfall-runoff computations, but the details of the API methods varied from office to office. A few offices, such as Atlanta and Portland used different rainfall-runoff methods. All except Portland's were event based procedures. Snowmelt procedures were generally based on degree-day methods (Cincinnati was an exception) with significant manual intervention required. Various forms of storage routing procedures were used by the RFCs with in-house developed techniques to handle more difficult situations.

The first model used by the RFCs that could be run in a continuous mode was the SSARR model, used by the Portland RFC. The initial SSARR snow routine required a seasonal water supply volume forecast to determine the current melt factor, thus the model couldn't be run for multi-year simulations by itself for snowmelt basins. Headquarters began experimenting with continuous conceptual models when I was hired. We used a slight modification of the Stanford watershed model for rainfall-runoff computations. The snow model was a variation of the model I had developed at Stanford. An attenuated time-delay histogram was used to model the channel system for headwaters. In the late 1960's it was decided that a comparison should be performed between the Stanford Model and an API based procedure. Since one was a continuous model and the other an event based procedure, a direct comparison wasn't possible. Walt Sittner was given the task of creating a continuous API model so a comparison could be performed (Sittner, Schauss and Monro, Water Resources Research, Vol. 5, No. 5, October 1969). When this was done, several watersheds were used for the comparison (Monocacy River in Maryland, Mad River in Ohio, Meramec River in Missouri, Leaf River in Mississippi, Bird Creek in Oklahoma, and the S. Yamhill River in Oregon). About this time Bob Burnash and others at Sacramento were developing the Sacramento Model (they had attended a workshop on the Stanford Model and liked the concept, but had different ideas on how to model the various components of the rainfall-runoff process). Bob also ran his model on the test basins. In addition the SSARR model was run for the test basins by the Portland RFC. At that point in time the modified version of the Stanford model produced the best overall results. A decision was then made to put together a system of programs that would enable the RFCs to test and implement a conceptual model. This effort culminated in 1972 with the release of NOAA Technical Memorandum NWS Hydro-14 "The National Weather Service River Forecast System Forecast Procedures".

Hydro-14 contained programs for the computation of MAP, historical streamflow simulation (referred to as the verification program), automatic parameter optimization (using a pattern search technique), and operational forecasting (only contained code to perform model computations – lag and K technique was used for channel routing). In order to facilitate the processing of historical precipitation data arrangements were made with NCDC to put hourly and daily precipitation observations in a easy to read tape format (previously only difficult to use punched cards were available). Myself and John Monro were the primary developers of the Hydro-14 programs with assistance from Vern Bissell, Chuck Schauss, and Walt Sittner.

One year later a program to compute MAT based on historical max/min temperature data and snowmelt simulation routines were added to the system – NOAA Technical Memorandum NWS Hydro-17 – "NWSRFS Snow Accumulation and Ablation Model". The report number was how the snow model became known as SNOW-17.

During the preparation of Hydro-14 an RFC was established at Slidell, LA. The decision was made to use the NWSRFS procedures to produce operational forecasts at Slidell. A software contractor was hired (Data Sciences Inc., DSI) to develop the code needed to process the data and provide the controls for the operational modeling code included in Hydro-14. The Slidell RFC was provided space in a NASA facility and given free computer time for several months. During this period the RFC used the optimization program to develop parameter values for the Stanford model for all their headwater basins. This was the first use of NWSRFS for operational forecasting.

After the release of Hydro-14 the Weather Service participated in a WMO inter-comparison of conceptual models used in operational forecasting. Based on the results of this comparison, it was decided to perform a more detailed in-house comparison of the Stanford and Sacramento Models. The basins used were those from the previous OH model comparison. The results were analyzed and recommendations prepared by myself, Walt Sittner, and John Monro. I recommended that the Sacramento model was an improvement over the Stanford model. Though the overall results were generally similar, when there were differences, the Sacramento model typically was better and the improvement could be directly linked to the algorithms used. The result of this comparison was that the Sacramento model would be the primary rainfall-runoff model for NWSRFS.

DSI was subsequently contracted to produce a more comprehensive NWSRFS operational system (referred to as versions 1-4 as incremental features were added). The result was improvements in terms of data entry, parameter maintenance, and data processing. Model computations were still limited to SNOW-17, Sacramento soil moisture accounting, time-delay histogram headwater routing, lag and K channel routing, and some limited reservoir capabilities. During this process NWSRFS was adopted for general use by the Tulsa RFC in addition to Slidell. In addition several other RFCs began using NWSRFS for MAP, MAT, and Snow computations though it didn't contain the methods and flexibility they needed for rainfall-runoff, routing, and reservoir operations.

For some time several of us in HRL had the idea that the forecast system needed to have the capability to have a wide array of models and that the users should be able to combine these models in whatever sequence was needed to produce the forecast. However, no one could figure out how to program such a system. Finally one of the new employees who was more computer savvy told me that when an array was passed through an argument list, it was a location that was passed and not the whole array. This knowledge lead to the concept of the operations table. Models and other procedures needed for operational forecasting could be programmed as modules. Large arrays could then be subdivided to store model parameters, carryover, and the computational sequence.

The first meeting of the Operational Program Advisory Group (OPAG) was held in Slidell in January 1979. OPAG was formed to provide advice to headquarters concerning the operational requirements of the RFCs and allow for feedback on NWSRFS. The group had one representative from each RFC. HRL presented the operations table concept at the meeting. OPAG recommended that a new version of NWSRFS be produced. The system was to be divided into 3 main components – data entry, preprocessing, and forecast computations. HRL volunteered to produce the forecast component. RFC groups planned to produce the data entry and preprocessor components. The new version was to be referred to as Version 5 of NWSRFS and would completely replace version 4 (previous versions had just built on one another).

Upon returning from the OPAG meeting Ed Johnson and I spent several months designing the routines and file structure for the forecast component. The design was presented to the OPAG Forecast Component Task group in Atlanta in October 1979. HRL then began coding and testing the forecast component routines. I coded the control portion of MCP. Larry Brazil coded the control portion of OPT. Ed Johnson started the coding of the FCINIT program and file access routines. When Ed left Joe Ostrowski took over this responsibility. George Smith took over from Ed as the 'computer expert' on the project and worked with me to develop requirements for the Processed Data Base (PDB), the Hydrologic Command Language (HCL), and run-time modifications (MODS). DSI was contracted to design and code the PDB and HCL. George developed the MOD routines. George ended up writing a Simplified Command Language (SCL) so that the forecast component could be tested prior to the completion of HCL. A majority of the HRL staff got involved by coding the various operations that were needed for both calibration and operational applications. RFC personal became involved in coding some of the operations. Randy Tetzloff (sp?) from

Tulsa designed and coded the primary operational display (PLOT-TUL). Ed Fox, the former HIC at Atlanta, worked with Joe Ostrowski to design and code a reservoir control operation. The initial testing of the forecast component was started at the Tulsa RFC in July of 1981.

While the forecast component was being developed and tested (testing was also begun at Minneapolis in addition to Tulsa) there was a lack of progress on the data entry and preprocessor components. In January of 1982 in Kansas City, in conjunction with a data systems meeting, the Director of OH, Bob Clark, announced that a Project Office was being established to complete the design and coding of Version 5.0. I was appointed Technical Project Manager of the Project Office. The Project Office consisted of both HRL and HSD personal. Field personal, while not under the direction of the Project Office, were still involved in the data entry component. Design documents were prepared for the MAP, MAT, MAPE, and RRS preprocessors, the PPINIT program, and the Preprocessor and Preprocessor Parametric Data Bases. DSI coded the data bases, Scott VanDemark the PPINIT program, and various HRL and HSD personal worked on the preprocessors. In addition personal from several RFCs began to code their API routines as operations. Testing of the Version 5 preprocessor component began in Tulsa in October 1983. While the envisioned comprehensive data base and quality control features for data entry were not accomplished as part of the Project Office, routines to pars and post SHEF data (primarily due to the efforts of Geoff Bonnin from Kansas City), and to automatically transfer synoptic and GOES observations to the PPDB were completed. The Project Offices mission was accomplished on time and the office was disbanded in late 1983.

In subsequent years more operations were added to NWSRFS, many by RFC personal. One of the largest efforts involved adding all the operations needed by Portland so that a transition could be made from SSARR to NWSRFS without affecting their relationship with the Corps. Another major addition was the creation of an interactive, graphical forecast program (IFP) in the early 1990s. The concepts from IFP were then used to create a similar program for calibration use (ICP). By the mid 1990s all the RFCs were using NWSRFS as their forecast system. Eventually all of the RFCs except one made the transition to the Sacramento model for rainfall-runoff computations (MARFC uses a Continuous API model). SNOW-17 is used by all the RFCs that include snow in their operations. A variety of routing and reservoir procedures are used by the river centers.

Note: As the National Weather Service hydrology program moves forward in the 21st century, NWSRFS is being retired and replaced with CHPS; the NWSRFS infrastructure component is being replaced in part by a third party software package called Delft-FEWS[1]. The legacy of NWSRFS is that most of its hydrologic software modeling elements are being migrated into CHPS to run with the new Delft-FEWS architecture. This move to CHPS will allow for rapid transfer of collaborative research into operations and will improve the RFCs' ability to take advantage of new science, and provide new services.

[1] Delft-FEWS was developed in the Netherlands by WL|Delft Hydraulics (now part of Deltares).